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International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

CHEMISTRY
HIGHER LEVEL
PAPER 3

Tuesday 19 May 2009 (morning)

1 hour 15 minutes

Candidate session number

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INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided. You may continue your answers on answer sheets. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the letters of the Options answered in the candidate box on your cover sheet and indicate the number of answer sheets used in the appropriate box on your cover sheet.

0130

Option A — Modern analytical chemistry

A1. (a) Distinguish between an absorption spectrum and an emission spectrum. *[2]*

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(b) Identify the most suitable spectroscopic technique to

(i) distinguish between butan-1-ol and butan-2-ol. *[1]*

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(ii) determine the concentration of cadmium ions in polluted water. *[1]*

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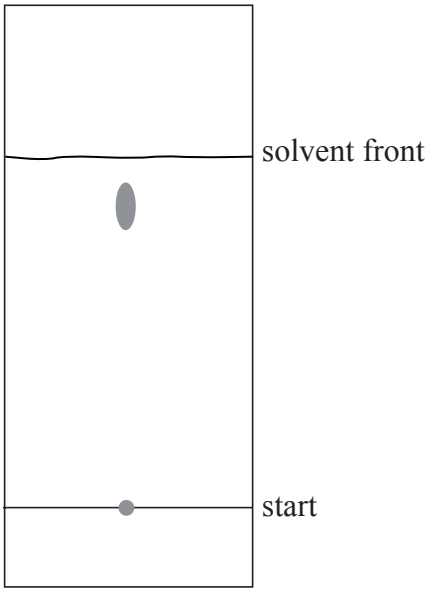
(c) The following diagram represents a thin-layer chromatogram of an amino acid.



(i) Outline the principle of thin-layer chromatography. Refer in your answer to the nature of the mobile and stationary phases and the reason why a mixture of amino acids can be separated using this method. *[2]*

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(This question continues on the following page)

(Question A1 continued)

(ii) State **one** advantage of thin-layer chromatography over paper chromatography. *[1]*

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(iii) Calculate the R_f of the amino acid. *[1]*

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A2. Mass spectrometry is a powerful analytical technique used in the identification of organic compounds. The mass spectrum of a compound with empirical formula CH_2O displays peaks at *m/z* 15, 45 and 60.

(a) Determine the molecular formula of the compound. *[1]*

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(b) Identify the fragments responsible for the peaks at *[2]*

m/z = 15 . . . . . .

m/z = 45 . . . . . .

(c) Identify a compound that could produce this spectrum. *[1]*

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A3. Infrared spectroscopy is an analytical technique that uses electromagnetic radiation.

(a) Describe briefly how a double-beam IR spectrometer operates. *[3]*

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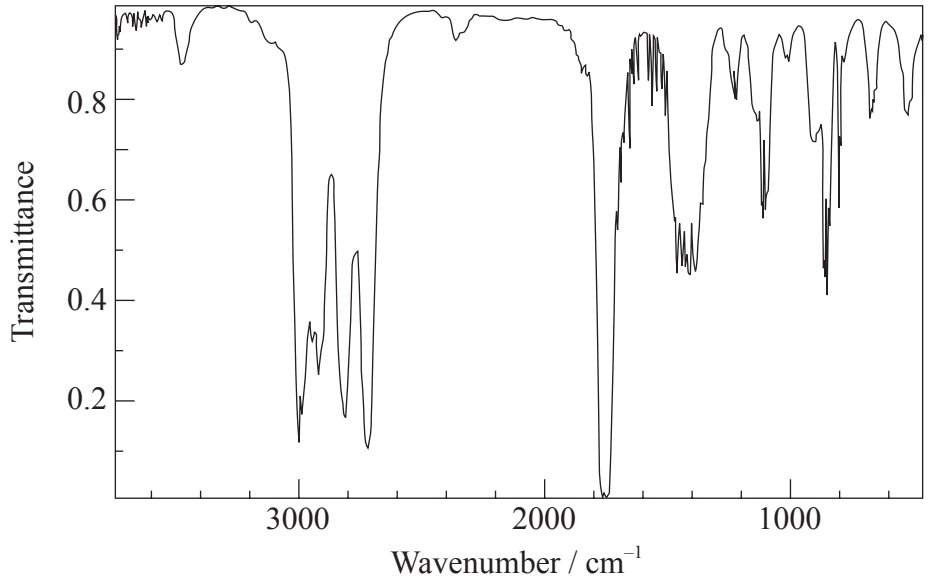
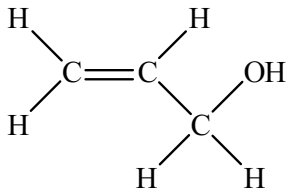
(b) The infrared spectrum of a substance, X, with empirical formula C_3H_6O is given below.



[Source: NIST http://webbook.nist.gov/chemistry]

(i) Explain why the structural formula of X **cannot** be: *[2]*



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(This question continues on the following page)

(Question A3 continued)

(ii) The ^{1}H NMR spectrum of X consists of three peaks. Deduce the structural formula of X and the relative areas under each peak. *[2]*

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(iii) Predict the splitting pattern of the peak with the biggest area. *[1]*

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A4. (a) Identify the feature that allows some organic molecules to absorb UV radiation. *[1]*

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(b) The wavelengths at which three compounds absorb UV radiation most strongly are given in the following table.

Compound	Wavelength / nm
1,4-pentadiene	177
1,3-pentadiene	223
1,3,5-hexatriene	258

Explain why the wavelength increases down the table. *[4]*

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Option B — Human biochemistry

B1. Glucose is a monomer of starch.

(a) Draw the straight-chain structure of glucose. *[1]*

(b) Explain why **two** cyclic isomers are formed from the straight-chain glucose and name both isomers. *[3]*

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(c) State the name of the **two** polymeric forms of starch. *[1]*

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B2. Cholesterol belongs to a class of substances named lipids.

(a) Identify the characteristic structural feature of cholesterol. *[1]*

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(b) Identify **two** other types of lipids found in the human body. *[2]*

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(c) (i) State what the terms *HDL* and *LDL* represent. *[1]*

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(ii) Outline **one** chemical difference between HDL and LDL. *[1]*

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(d) Describe **one** negative effect of a high concentration of LDL cholesterol in blood. *[1]*

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B3. Vitamins are micronutrients essential for good health.

(a) Compare the solubilities of vitamins A and C in water by referring to the structures provided in Table 21 of the Data Booklet. *[2]*

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(b) Describe the effect of deficiency of **one** of these vitamins and suggest **two** possible solutions. *[3]*

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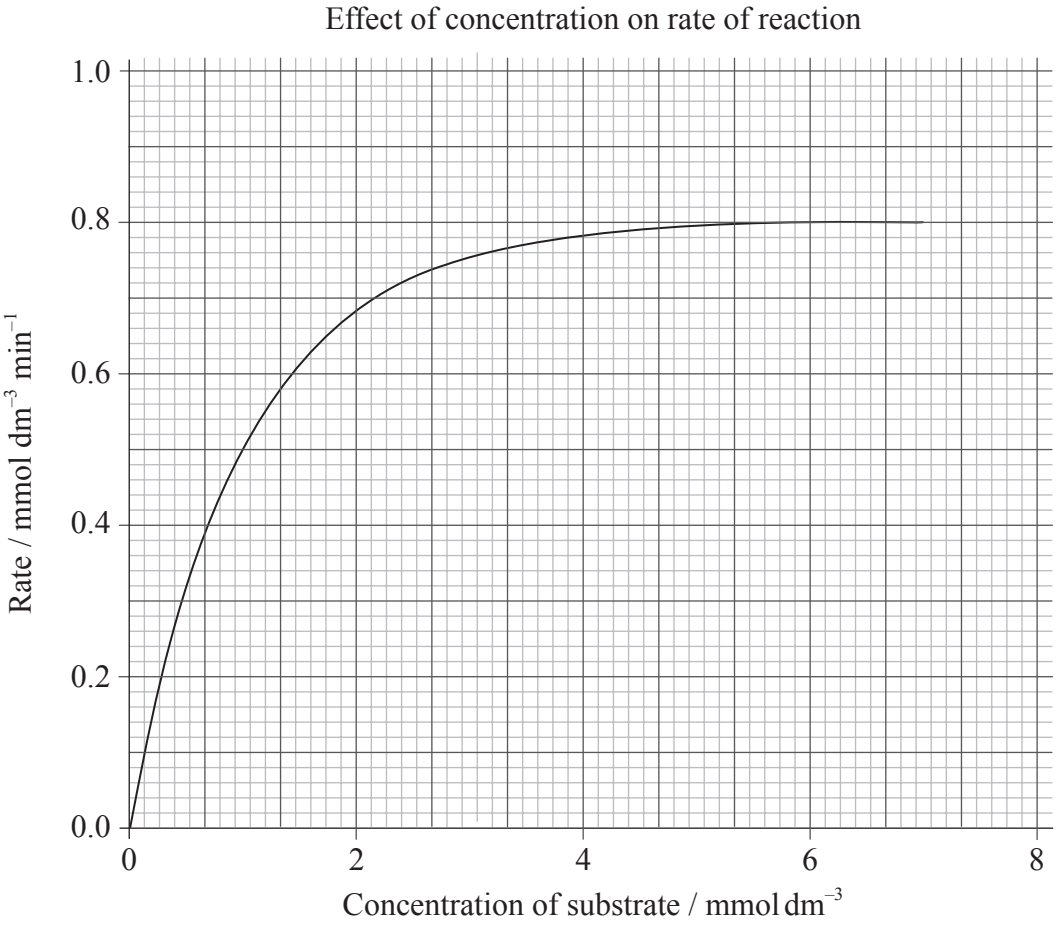
B4. The following graph shows the effect of substrate concentration on the rate of an enzyme-catalysed reaction.



(a) Explain the relationship between enzyme activity and concentration of the substrate. *[2]*

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(b) Determine the Michaelis constant K_m from the graph. *[1]*

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(This question continues on the following page)

(Question B4 continued)

(c) Describe why competitive inhibition may take place. *[1]*

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(d) Explain the effect of competitive inhibition on V_{max} and K_m. *[4]*

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(e) On the graph of effect of concentration on rate of reaction on page 10, sketch the expected curve for **non**-competitive inhibition. *[1]*

Option C — Chemistry in industry and technology

C1. Alloys are important substances in industries that use metals.

(a) Describe an alloy. *[1]*

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(b) Explain how alloying can modify the structure and properties of metals. *[2]*

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(c) Describe the effect of the *tempering* process on steel. *[1]*

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(d) Discuss the environmental impact of iron and aluminium production. *[2]*

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C2. The high activity of lithium metal leads to the formation of an oxide layer on the metal which decreases the contact with the electrolyte in a battery.

(a) Describe how this is overcome in the lithium-ion battery. *[2]*

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(b) Describe the migration of ions taking place at the two electrodes in the lithium-ion battery when it produces electricity. *[2]*

Anode (–):

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Cathode (+):

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(c) Discuss **one** similarity and **one** difference between fuel cells and rechargeable batteries. *[2]*

Similarity:

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Difference:

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C3. (a) Compare the positional and directional order in a crystalline solid, nematic phase liquid crystal and a pure liquid. Show your answer by stating **yes** or **no** in the table below. *[2]*

	Crystalline solid	**Nematic phase liquid crystal**	**Pure liquid**
Positional order			
Directional order			

(b) Outline any **two** principles of a liquid-crystal display device. *[2]*

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C4. Polymers, used extensively worldwide, are large molecular mass substances consisting of repeating monomer units.

(a) State the type of mechanism occurring in the manufacture of low-density poly(ethene). *[1]*

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(b) State the equation for the reaction of the alkoxy free radical, RO•, with ethene and describe the movement of electrons that take place in the process. *[3]*

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(c) Distinguish between *addition* and *condensation* polymers in terms of how the monomers react together. *[2]*

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(d) Describe and explain how the properties of condensation polymers depend on three structural features. *[3]*

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Option D — Medicines and drugs

D1. Medicines and drugs can influence the functioning of the body.

Discuss the term *therapeutic window*. Your answer should include its meaning, a quantitative description and an explanation of **wide** and **narrow** therapeutic windows. *[4]*

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D2. Chemists can change structures of substances in order to produce chemicals with desired properties.

(a) Aspirin is virtually insoluble in water. Use Table 20 in the Data Booklet to explain how aspirin can be made more water-soluble. Write an equation for the reaction. *[2]*

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(b) Prozac®, fluoxetine hydrochloride, a depressant, is water-soluble and is made by reacting fluoxetine with hydrochloric acid. Use Table 20 in the Data Booklet to deduce the structure of fluoxetine. *[1]*

D3. Ethanol, a depressant, is sufficiently volatile to pass into the lungs from the bloodstream. The roadside breathalyser test uses acidified potassium dichromate(VI) which reacts with any ethanol present in the breath and converts it to ethanoic acid.

(a) (i) State the oxidation and reduction half-equations that occur in the breathalyser when ethanol is present in the breath. *[2]*

Oxidation:

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Reduction:

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(ii) Describe the colour change that occurs to the acidified dichromate(VI) if ethanol is present in the breath. *[1]*

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(b) Police use the intoximeter, an infrared spectrophotometer to confirm a roadside breathalyser test. Explain how the amount of ethanol is determined from the infrared spectrum. *[2]*

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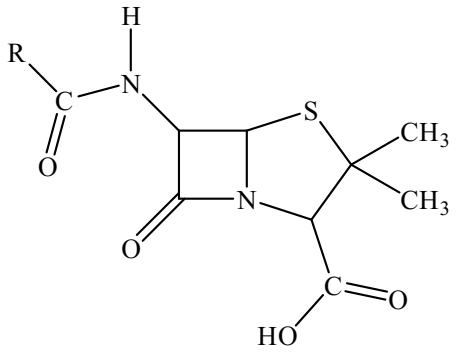
D4. Antibacterials are drugs that kill or inhibit the growth of microorganisms that cause infectious diseases. The general structure of penicillin, an antibacterial, is given below.



(a) With reference to the structure above, state what the letter R represents and discuss how penicillins can be made more resistant to the penicillinase enzyme. *[2]*

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(b) Describe the composition and structure of the beta-lactam ring in penicillin and explain its importance. *[5]*

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(c) Describe and explain **one** effect of overprescription of antibacterials. *[2]*

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D5. Describe and explain difficulties associated with solving the AIDS problem. *[4]*

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Option E — Environmental chemistry

E1. The exhaust gases of automobiles contribute significantly to air pollution in cities.

(a) Outline how the pollutant gases nitrogen(II) oxide, NO, nitrogen(IV) oxide, NO_2 and carbon monoxide, CO, are formed as a result of the action of the internal combustion engine. *[3]*

NO:

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NO_2:

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CO:

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(b) One way to reduce automobile pollution is to control the fuel to air ratio. Discuss the impact of **increasing** the fuel/air ratio on the concentrations of volatile organic compounds (VOC's), CO and NO in exhaust gases. *[3]*

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E2. Chlorofluorocarbons, CFCs, deplete the ozone layer.

(a) State the equations that represent the depletion of ozone in the stratosphere which is catalysed by chlorine free radicals. *[2]*

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(b) Chlorine atoms and nitrogen oxides react at the surface of ice particles in the arctic winter.

(i) Deduce the type of catalysis that occurs. *[1]*

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(ii) Outline why the depletion of ozone is greatest during the arctic spring. *[2]*

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E3. Explain, using appropriate equations, the role of ammonia in acid deposition. *[5]*

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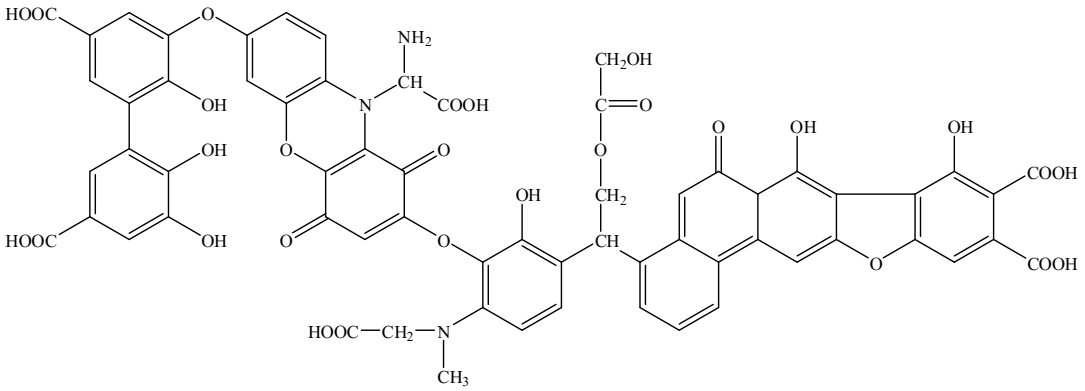
E4. (a) The following molecule is found in soil organic matter, SOM.



(i) State a main constituent of SOM. *[1]*

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(ii) Explain, with reference to the structure above, how SOM can increase the soil quality, in terms of the following. *[3]*

Provision of nutrients:

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Water retention:

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(b) Discuss how irrigation can cause soil degradation. *[3]*

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(This question continues on the following page)

(Question E4 continued)

(c) State the name of **one** source for each of the following organic soil pollutants. *[2]*

Polyaromatic hydrocarbons (PAHs):

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Organotin compounds:

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Option F — Food chemistry

F1. (a) Describe the chemical composition of a triglyceride. *[1]*

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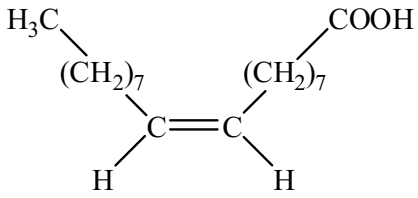
(b) The following two structures represent isomers of a fatty acid.



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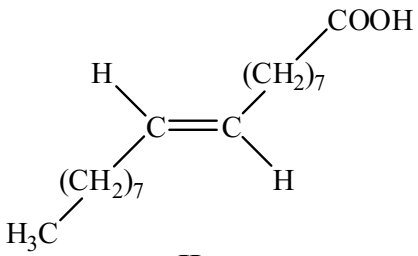

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State and explain which isomer has the higher melting point. *[3]*

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(c) Outline the process of hydrogenating fats and name **one** catalyst for the process. *[2]*

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F2. The label of a can of meat indicates that it has the following ingredients:

Meat, water, salt, spices, sodium ascorbate, sodium nitrite, sodium tripolyphosphate, flavourings and paprika extract.

(a) List the **two** main nutrients found in the can of meat. *[2]*

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(b) Outline how canning increases the shelf life of the meat. *[2]*

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(c) State the function of

(i) sodium nitrite. *[1]*

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(ii) sodium ascorbate. *[1]*

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F3. (a) Explain why raw meat changes colour from purplish-red to brown on standing. *[3]*

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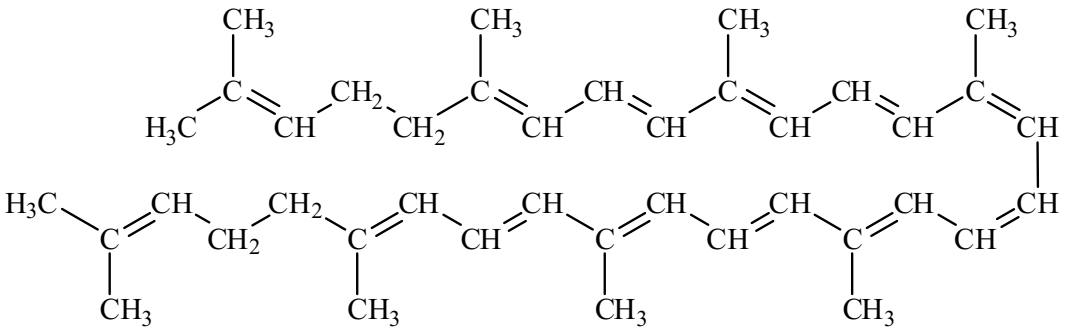
(b) Lycopene, whose structure is shown below, is a carotenoid and is responsible for the red colour in tomatoes. When bromine is slowly added to some tomato juice, the colour of the juice gradually changes from red to yellow. Explain this colour change in terms of changes in bonding in lycopene. *[3]*



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F4. A chelating agent is one type of antioxidant.

(a) State the name of **one** example of a chelating agent. *[1]*

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(b) State the name of **one** other **type** of antioxidant. *[1]*

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(c) Explain the difference in action of BHT and β-carotene as antioxidants, with reference to their structure provided in Table 22 of the Data Booklet. *[5]*

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Option G — Further organic chemistry

G1. Benzene is an important molecule containing delocalized electrons.

(a) Explain the term *delocalized electrons*. *[1]*

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(b) State and explain **one** piece of physical evidence and **one** piece of chemical evidence for the presence of delocalized electrons in the structure of benzene. *[4]*

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(c) Describe and explain the relative rates of the reactions of hydroxide ions with chlorobenzene, C_6H_5Cl, and (chloromethyl)benzene, $C_6H_5CH_2Cl$. *[3]*

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(This question continues on the following page)

(Question G1 continued)

(d) State the name of the product formed from the chlorination of nitrobenzene in which one chlorine atom is introduced into the benzene ring. Describe and explain the effect of the **nitro** group on the reaction. Your answer should include a comparison of the rate of chlorination of benzene to that of nitrobenzene. *[5]*

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G2. Draw the structural formulas of the **two** elimination products formed when butan-2-ol, $CH_3CH_2CH(OH)CH_3$ is heated with phosphoric acid. *[2]*

G3. (a) Outline the formation of a Grignard reagent. Include any necessary conditions. *[2]*

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(b) 2-methylbutan-2-ol is formed by the reaction of a ketone with a Grignard reagent. Draw the structural formula of 2-methylbutan-2-ol and deduce the structural formulas of the ketone and the Grignard reagent used for the reaction. *[3]*

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G4. State the equation for the reaction of ethanoyl chloride, CH_3COCl, with sodium hydroxide. Identify the mechanism for the reaction and explain it using curly arrows to show movement of electron pairs. *[5]*

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